PAV-90-03

# Field Evaluation of Rout and Seal Crack Treatment in Flexible Pavements

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Ministry of Transportation

Research and Development Branch

# Technical Report Documentation Page

## Field Evaluation of Rout and Seal Crack Treatment in Flexible Pavements

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| Abstract: | This report documents a four year study on the evaluation of rout and seal crack treatment for flexible pavements conducted by the Ministry of Transportation, Ontario. The study includes the selection of 37 test sites across Ontario covering different climatic and environmental conditions. Each test site was divided into five sections, 750 m long with the control section in the middle. The performance of each individual test section has been carefully monitored over the past four years through condition surveys and photographs. Also, roughness measurements and cored samples were taken when time and resources permitted. A three part analysis was carried out and the results are presented in this report. The analysis investigates: (1) the effect of rout configuration on sealant bond failure, (2) the influence of treatment on pavement distress manifestation, and (3) cost-effectiveness of this treatment in terms of extended pavement life.<br><br>The results indicate that the sealant bond failure in 40x10 mm (40 mm wide x 10 mm deep) rout configuration is significantly less than that in 19x19 or 12x12 mm rout size. Secondly, the rout and seal treatment seems to be successful in retarding the secondary crack growth and subsequently reducing the pavement distress manifestation index (DMI). Finally, the cost-effectiveness study based on limited data seems to indicate that the treatment has the potential to increase pavement life by about 3-4 years. |
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## 1. INTRODUCTION

It has long been recognized that roads and highways need improvements periodically to maintain the acceptable level of serviceability over the course of their design life. One of the major distresses that requires timely action to prevent accelerated pavement deterioration is cracking. Time has shown that sealing with emulsified asphalt, a traditional maintenance treatment for cracks, is not only ineffective, but also can create undesirable side effects; subsequently, this method leads to poor riding quality of the pavement surface [1]. In view of the growing demand for improved methods of treating cracks, the Ministry of Transportation of Ontario embarked upon a program in 1981 to investigate the feasibility of using a rout and seal treatment for cracks in flexible pavements as a preventive maintenance procedure. Consequently, a small preliminary experimental field study employing rout and seal method for crack treatment was initiated in the Ottawa district . The results of the initial study apparently increased confidence in the use of the method and opened the way for further development of a province-wide experimental field study.

In 1986, a comprehensive study, covering different climatic and environmental conditions, was carried out involving the selection of 37 test sections in all the regions of Ontario except the Northwestern region. The main thrust of this project was to provide a basis to address such key issues as:

1) optimum timing for application of this treatment,

2) suitable rout size that provides better bonding of sealant materials,

3) cost-effectiveness of this method in increasing the life expectancy of pavements.

The previous report [2] by George Chong indicated clearly that the optimum timing for rout and seal is between the third and fifth year of pavement service life. He also discussed subjectively the effect of rout configuration on sealant bond failures. The purpose of this report is to address the last two issues in a more rational and objective way within the limits of the field data acquired hitherto.

## 2. SCOPE AND OBJECTIVES

The general purpose of this report is to discuss the influence of rout and seal treatment on the relative performance of test sections measured as a function of pavement distress and roughness. More specifically, the objectives of this report can be stated as follows:

1) To investigate the effect of rout configuration on sealant bond failures.

2) To analyze statistically the influence of rout and seal treatment on distress manifestation, secondary crack growth, and pavement condition index.

3) To examine, using the available data, the cost effectiveness of rout and seal treatment as a preventive maintenance procedure.

It is to be noted that the sealant materials were obtained from the approved designated sources and as such no attempt will be made to evaluate the comparative performance of these products in terms of bond failures.

## 3. FIELD INVESTIGATION

As discussed previously in section 1, a field experimental study was initiated in 1986 across the province of Ontario to incorporate the influence of different climatic and environmental conditions on rout and seal crack treatment. This program entailed the selection of a range of pavement sections from 3 different age groups: less than 3 years, 4-6 years, and 7-9 years. A detailed description of the test sites selected for this study is given in the following section.

### 3.1 PAVEMENT TEST SITES

A total of 31 test sites were evaluated during the cold winter period of the year 1990, of which 18 test sites were located in South Western region, 2 in the Central region, 4 in the Northern region, and 7 in the Eastern region. Each site was divided into five sections and the cracks in all sections, except the middle one, were treated using rout and seal method. The cracks in the middle section were left untreated for the purpose of a comparative evaluation. A rout configuration of 40x10mm (40mm wide x 10mm deep) was used for the first and the fourth sections of all the test sites, 12x12mm was used for the second and the fifth sections of the sites located in districts 1-4 and 6 in the Southwestern region, and the remaining test sites used 19x19mm rout configuration for these sections.

### 3.2 SEALANT MATERIALS

The sealant materials used for sealing the routed cracks were Hydrotech 6165, Hydrotech 6160, and Tremco 205 which were supplied by the approved designated sources. Reference [3] provides the location, rout size, and materials used for the all the sections.

### 3.3 METHOD OF ROUTING AND SEALING CRACKS

A detailed description of the equipment and work procedures involved in crack sealing operation is given in references [2,3]. This method, originally developed by the Pavement and Roadway Office and the Ottawa District Maintenance Office, proved to be highly efficient and productive in the application of rout and seal treatment to cracks in flexible pavements.

## 4. METHOD OF EVALUATION.

The method of evaluating the rout and seal sections can be categorized into three groups:

1) the effectiveness of this treatment to prevent water from entering into the pavement structure and causing deterioration of pavement layers,

2) the influence of this treatment on pavement distress, and

3) the cost effectiveness of this method in terms of extending the pavement life.

The effectiveness of this treatment to prevent the intrusion of water into the cracks is assessed in terms of sealant bond

*failure which is measured as follows:*

$$B = b_i/n$$

*where,* $b_i$ = *percent bond failure per crack length,*

$n$ = *number of cracks in each section, and*

$B$ = *average percent bond failure per section.*

*Figure 1 provides the rating form specifically designed to evaluate the sealant debonding on one side or both sides of individual cracks. This form is actually a supplement to the existing standard condition rating form used for pavement condition survey in Ontario. This new form allows the assessment of bond failures on a crack by crack basis.*

*The influence of the rout and seal treatment on pavement distress is assessed by comparing the crack growth and distress manifestation index (DMI) of treated sections with those of the control section. Crack growth is calculated by estimating the difference between the initial and final crack length measured in terms of linear meters.*

*Distress manifestation index (DMI) is defined as [4]:*

$$DMI = W_i (S_i + d_i) \qquad (2)$$

where $W_i$ = Weighting value representing the relative weight of each distress manifestation on a scale from 0 to 3,

$S_i$ = severity of distress manifestations expressed on a scale from 0 to 4, and

$d_i$ = density of distress occurrence expressed on a scale from 0 to 4.

DMI for each section is computed according to the procedures outlined in reference [5]. It should be noted that rutting is not included in the estimation of DMI for rout and seal test sections.

Finally, a cost effectiveness analysis for this treatment is carried out. In general, such analysis depends on several local factors, including pavement thickness and age, traffic loads, climate, maintenance and rehabilitation policy, etc.. Since cost effectiveness analysis is the most important aspect of this study, the following section will be devoted to describing the method of such analysis based on the projected lives of pavements.

## 4.1 COST EFFECTIVENESS ANALYSIS

Cost-effectiveness analysis is an economical analysis which deals with impacts or benefits that are not easily quantifiable or for which there are no defined dollar values. In the maintenance treatment of highway projects most of the impacts and objectives are difficult to measure in monetary terms. As a result, one is confronted frequently with problems in reaching project level decisions with regard to proposed treatments on the basis of economics. These decisions mostly rely on judgment and program objectives.

The main focus of this section is to assess the benefits of the rout and seal treatment in terms of the extended pavement life. This assessment is achieved by comparing the performance of treated and control pavement sections. Therefore, the principal issue is to establish performance curves for the test sections using the available data. The performance is measured in terms of PCI defined by the following Equation [4].

$$PCI=100(0.1xRCR)^{1/2}(205-DMI)/205 \qquad (3)$$

Where, $PCI<100$,

$DMI$= distress manifestation index,

205= probable maximum value of DMI,

$RCR$= 9.38-0.0177(Roughness using Mays meter)

A graph of the average PCI versus age will be plotted using the data acquired over the past 4 years and the results will be extrapolated to estimate the expected pavement lives.

## 5. DATA ANALYSIS

The data acquired through the field condition survey of the rout and seal test sections in Ontario is processed and analyzed to investigate the effect of rout size on bonding of sealant materials and the merits of using rout and seal crack treatment to increase the overall pavement performance. The following sections present the findings of the investigation.

### 5.1 EFFECT OF ROUT CONFIGURATION ON SEALANT BONDING

The effect of rout configuration on bonding is assessed by the average percent bond failure of sealant materials. Two sets of pairs are considered in the analysis: the first set comprises a rout size combination of 40x10&19x19mm; the second set has a combination of 40x10&12x12mm as shown in Tables 1 and 2. These Tables show that the rout size of 40x10mmm has a better performance record than the others. The statistical significance of the observed difference between the performance of the two rout sizes are analyzed using the paired t-test, which allows the comparison of two methods of treatment in pairs under experimental conditions as similar as possible.

In Table 1, the average percent bond failure of 19x19mm rout test sections are given in column 1, and those of 40x10mm rout test sections are given in column 2. The differences are given in column 3. In order to determine whether these differences are significant or not, the paired t-test was carried out as follows:

For paired comparisons, it is assumed that the populations of the differences "d" are normally distributed. The first step in any statistical procedure for comparing the means from two different populations is to formulate the hypothesis that is being tested (known as null hypothesis:$H_0$). In this case, the null hypothesis is $H_0$:d=0; this means that there is no difference ($d=d_1-d_2$) between the bond failures of the two rout sizes of interest. The value of "t" for the data given in Table 1 is calculated using the following equation:

$$t = dxn^{0.5}/s$$

$$= (14.27x4.5825)/20.58$$

$$= 3.176 > 2.086$$

where, $n$ = number of observations,

$s$ = variance, and

2.086 = the value of "t.05" obtained from statistical table at 5% significance level.

The decision rule is that the null hypothesis is rejected if t >t.05

when the alternative hypothesis is $d_1 > d_2$. Since the observed value of t is greater than $t_{.05}$, the null hypothesis is rejected and the alternative hypothesis is accepted. This means that the bond failure in the rout size of 19x19mm is greater than that in the rout size of 40x10mm as illustrated in Figure 2.

Similarly, the bond failure between rout sizes of 12x12mm and 40x10mm are compared in Table 2. The observed value of t is 3.71 which is greater than $t_{.05}$ (1.796). Hence, the null hypothesis is rejected and the alternative hypothesis of bond failure in the rout size of 12x12mm being significantly greater than that in 40x10mm is accepted. The difference in bond failures between these sections is illustrated in Figure 3.

The above analyses indicate that the most effective rout size for flexible pavements is 40x10mm; consequently, the subsequent performance evaluation of the rout and seal treatment will include only the test sections having a rout size of 40x10mm.

### 5.2 THE INFLUENCE OF ROUT AND SEAL TREATMENT ON CRACK GROWTH AND DISTRESS MANIFESTATION INDEX

The secondary crack development is measured in terms of linear meters and is divided into two groups: transverse cracking; and total cracking, which includes transverse, longitudinal, edge, and center cracking.

Figures 4-7, provide the crack growth for pavement test sections located in different regions of Ontario. Figure 4, shows that there is a significant increase in total crack growth in control sections as compared to the treated sections in Northern Ontario. With respect to transverse cracking, the increase is marginal in control sections.

Figure 5 compares the crack growth in test sections in the Central region. As can be seen there is no evidence to suggest that treated sections performed better than the control sections. However, the results are inconclusive because of limited results. In Figure 6, the total crack growth in the test sections in Southwest region were compared. Of the 18 test sites, 7 of them indicate a relative increase in crack growth in the control sections as compared to both treated sections. The next 7 sites show that at least one of the treated sections performed better than the control sections, and the remaining 4 sites indicate no improvement in the treated sections.

In regard to transverse cracking, 9 test sites indicate (Figure 7) that both of the treated sections performed better than the control sections; 5 test sites show improvement at least in one of the treated sections; and the remaining 4 sites suggest that the treatment is ineffective.

Figure 8 examines the relative performance of the test sites in the Eastern region. Both of the treated sections showed

evidence of enhanced performance in 3 of the 6 test sites and the remaining 3 indicate that the treatment has no influence on secondary crack growth.

Finally, a statistical analysis was carried out using the data from all the test sites to examine the influence of rout and seal treatment on secondary crack growth in Ontario flexible pavements. The results are summarized in Table 3 which gives the difference in the crack growth between the control and treated sections. A paired t-test was performed as follows to determine the statistical significance of the observed difference.

For transverse crack growth, the observed t value is 1.947 which is greater than 1.67 (the value of $t_{.05}$) indicating that the crack growth difference between the control and treated sections is significant. Based on 60 observations, the average increase in crack growth in control sections is about 22% higher than that in treated sections.

The observed t value for total crack growth is 1.0019, which is less than the value of $t_{.05}$ (1.67), indicating that there is no significant difference between the performance of treated and control sections. However, a close examination of the observed data indicates that the 34th observation may be an outlier

because of an unusually large value for longitudinal cracking in the treated section. This result may be due to poor construction technique or the materials used in this section. Therefore, the analysis was repeated without the 34th observation and the new t value is found to be 4.10>1.67. Hence, the results based on 59 observations indicate that the total crack growth difference between control sections and treated sections is significant. The average crack growth in the control section is about 21% higher than that in the treated section.

A similar analysis was carried out to determine the influence of the treatment on the distress manifestation index (DMI). Table 3 shows that the value of t for the paired data is 6.82, which is greater than $t_{.05}$ (1.67) indicating that the difference is statistically significant between the control and treated sections. The latter has the average value of 4.72 which is less than one-half the value for the control section (9.565). Figures 9-12 compare the increase in DMI values for the control sections with those of the treated sections in different regions of Ontario.

In summary, based on the above analysis, it can be concluded that the rout and seal treatment has the tendency to minimize the potential damage in flexible pavements.

## 5.3. COST EFFECTIVENESS COMPARISONS

As discussed previously, the cost effectiveness analysis is carried out by comparing the performance of treated sections with that of the control sections. The main focus here is on the conceptual and statistical development of performance curves for the test sections based on the pavement condition index which is expressed as a function of the roughness and the distress manifestation index. It should be noted that the roughness data is only available for the first year and the current year as well as being confined to 10 test sites (Table 4). This limits the number of PCI points to 2. To develop a curve, a minimum of 3 points are required. Hence, it is assumed that the control section will reach a terminal PCI value of 50 in 1998; i.e. after 17 years of service, since the average age of the sections considered for this analysis was 5 years in 1986. Using this assumption, a performance curve was drawn for the control section as shown in Figure 13. Based on the shape of this curve, and using the available PCI points, similar curves are drawn for the treated sections. As the average PCI values for the 2 sets of treated sections are almost equal, their corresponding performance curves are also identical and overlap each other. However, as shown in Figure 13, two performance curves for the treated sections illustrate two probable extreme rates of pavement deterioration: one assumes an accelerated deterioration in relation to the other. Obviously, these curves rely on a judgment based on their performance in

the first 4 years of their service. These performance curves indicate that the expected increase in pavement life for the treated sections can range from 2-5 years depending on the environment, traffic, and original age of the pavement. It should be noted that the anticipated minimum 2 years of extended life is extremely conservative in comparison to the estimated 1 year at the fourth year of their service as shown in Figure 13.

Further analysis was carried out to determine whether or not the observed differences in the performance (as measured in terms of PCI) of the control and treated sections after 4 years of service are statistically significant. Table 5 gives the differences in the reduction of PCI values between the control and treated sections. The observed "t" value for the paired data is 5.97 which is greater than 1.729 ($t_{.05}$) indicating that the differences are statistically significant.

Finally, from the standpoint of agency maintenance costs, it appears that it would be more cost-effective to continue the rout and seal treatment at the average cost of $1.17 per linear metre (as of 1987)in return for the extended average pavement service life of 3-4 years. Also, it should be noted that a relatively better performance of a future overlay on the treated section is expected as a result of the well preserved structural integrity of the old pavement which received the rout and seal treatment. A more detailed cost analysis that quantifies these factors might show that the benefits realized in terms of low

maintenance costs and user costs associated with the future overlay on treated sections will outweigh the initial agency costs for the treatment.

## 6. INVESTIGATION OF CORED SAMPLES

Up to the time of writing this paper, limited cored samples were taken in 3 test sites in the Southwestern region. Examination of these samples indicated that the rout and seal treatment seemed to have minimized the moisture induced damage; i.e. the loss of aggregates, debonding at the interface between the old pavement surface and the overlay near the crack, erosion at the bottom of the underlying layers, etc. Such damage is expected to reduce the structural strength of the entire pavement resulting in the manifestation of increased surface distress. This explains why the observed crack growth and the distress manifestation index in control sections are significantly greater than that in the treated sections.

## 7 CONCLUSIONS

This evaluation provides valuable information about the performance and cost-effectiveness of rout and seal crack treatment. This information can be summarized as follows:

1) *Rout size of 40x10mm is more effective in minimizing the sealant bond failure and thereby preventing the intrusion of water into the pavement through the crack opening.*

2) *Rout and seal crack treatment seems to have some influence in retarding the secondary crack growth and subsequently reducing the pavement distress index.*

3) *Cost-effective analysis, based on limited results, indicates that this treatment appears to extend a pavement service life by about 3-4 years.*

4) *Investigation of cored samples from 3 test sites confirmed the general belief that the rout and seal treatment preserves the overall structural integrity of flexible pavements.*

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**Table 1. Comparison of Sealant Bond Failure - Rout Configuration: 19 x 19 mm vs 40 x 10 mm**

| Site No. | Obser No. | Bond Failure % | | Difference (d) (1) - (2) |
|---|---|---|---|---|
| | | 19 x 19 (1) | 40 x 10 (2) | |
| 1 | 1 | 41 | 19 | 22 |
| | 2 | 28 | 0 | 28 |
| | | | | 0 |
| 3 | 3 | 26 | 9 | 17 |
| | 4 | 6 | 2 | 4 |
| 4 | 5 | 98 | 48 | 50 |
| | | - | - | - |
| 28 | 6 | 0 | 0 | 0 |
| | 7 | 0 | 0 | 0 |
| 26 | 8 | 6 | 2 | 4 |
| | 9 | 0 | 0 | 0 |
| 25 | 10 | 0 | 0 | 0 |
| | 11 | 0 | 0 | 0 |
| 32 | 12 | 12 | 3 | 9 |
| | 13 | 13 | 31 | -18 |
| 33 | 14 | 40 | 28 | 12 |
| | | - | - | - |
| 34 | 15 | 50 | 2 | 48 |
| | 16 | 30 | 50 | -20 |
| 35 | 17 | 73 | 13 | 60 |
| | 18 | 32 | 4 | 28 |
| 37 | 19 | 49 | 42 | 7 |
| | | - | - | - |
| 29 | 20 | 68 | 50 | 18 |
| | 21 | 86 | 56 | 30 |

Mean Value of d = 14.27
Std. Deviation S = 20.50
Number of Observations = 21

**Table 2. Comparison of Sealant Bond Failure - Rout Configuration: 12 x 12 mm vs 40 x 10 mm**

| Site No. | Obser No. | Bond Failure % | | Difference (d) (1)-(2) |
|---|---|---|---|---|
| | | 12 x 12 (1) | 40 x 10 (2) | |
| 18 | 1 | 18 | 5 | 13 |
| | 2 | 20 | 0 | 20 |
| 19 | 3 | 61 | 13 | 48 |
| | 4 | 20 | 2 | 18 |
| 20 | 5 | 38 | 12 | 26 |
| | 6 | 24 | 0 | 24 |
| 21 | 7 | 13 | 11 | 2 |
| | 8 | 8.5 | 1.5 | 7 |
| 22 | 9 | 67 | 16 | 51 |
| | 10 | 5 | 1 | 4 |
| 23 | 11 | 11 | 0 | 11 |
| | 12 | 80 | 14 | 66 |

Mean Value of d = 22.5
Std. Deviation S = 21
Number of Observations = 12

**Table 3 . Difference in Crack Growth and DMI Increase Between Control and Treated Sections**

| Site No. | Observation | Cr. Growth Diff. | | DMI Difference |
|---|---|---|---|---|
| | | Trans-verse (m) | Total (m) | |
| 1 | 1 | 16 | 79 | 4.25 |
| | 2 | 26 | 78 | 12.25 |
| 3 | 3 | 10 | 118 | -8.63 |
| | 4 | 2 | 90 | -0.25 |
| 4 | 5 | 4 | 26 | 5.37 |
| | 6 | 13 | -9 | -1.25 |
| 6 | 7 | 14 | 35 | 9.30 |
| | 8 | 32 | 76 | 8.63 |
| 7 | 9 | 0 | 70 | -3.88 |
| | 10 | 29 | 22 | -2.25 |
| 8 | 11 | 32 | -5 | 13.0 |
| | 12 | 25 | 49 | 11.5 |
| 9 | 13 | 31 | 15 | 2.12 |
| | 14 | 11 | -28 | -0.5 |
| 10 | 15 | 2 | -1 | 2.08 |
| | 16 | 7 | 17 | 1.33 |
| 11 | 17 | 7 | 15 | -5.75 |
| | 18 | -3 | 0 | -0.13 |
| 12 | 19 | -12 | -10 | 6.25 |
| | 20 | -12 | -12 | 7.0 |
| 13 | 21 | -33 | 76 | 1.62 |
| | 22 | 4 | -17 | 2.87 |
| 14 | 23 | 7 | 71 | 14.37 |
| | 24 | 3 | 106 | 7.12 |
| 15 | 25 | 66 | 59 | 10.12 |
| | 26 | 33 | 42 | 7.25 |
| 17 | 27 | 4 | 7 | 26.50 |
| | 28 | 6 | 26 | 13.0 |
| 18 | 29 | -4 | 15 | 6.75 |
| | 30 | -1 | 56 | 2.0 |

| Site No. | Observation | Cr. Growth Diff. | | DMI Difference |
|---|---|---|---|---|
| | | Trans-verse (m) | Total (m) | |
| 19 | 31 | 32 | 57 | 6.38 |
| | 32 | 75 | 108 | 1.38 |
| 20 | 33 | 4 | 91 | 0 |
| | 34 | -8 | -297 | 0 |
| 21 | 35 | -4 | -43 | 5.25 |
| | 36 | 10 | 38 | 2.50 |
| 22 | 37 | -12 | 47 | 4.0 |
| | 38 | 7 | 5 | 4.0 |
| 23 | 39 | 1 | -1 | 5.12 |
| | 40 | 9 | 9 | 4.0 |
| 25 | 41 | 7 | 19 | 2.5 |
| | 42 | 1 | -25 | 5.5 |
| 26 | 43 | 41 | 73 | 8.38 |
| | 44 | 55 | 67 | 10.25 |
| 27 | 45 | 126 | -63 | -0.3 |
| | 46 | 24 | 29 | 5.5 |
| 28 | 47 | -14 | -27 | 1.5 |
| | 48 | 3 | 23 | -0.75 |
| 29 | 49 | -17 | -90 | 10.0 |
| | 50 | -10 | -7 | 6.0 |
| 32 | 51 | -14 | -8 | 10.0 |
| | 52 | -11 | -27 | 3.0 |
| 33 | 53 | 11 | 20 | 8.25 |
| | 54 | 7 | 30 | 4.00 |
| 34 | 55 | -2 | 0 | 11.00 |
| | 56 | 9 | -49 | 6.50 |
| 35 | 57 | -6 | 11 | 2.5 |
| | 58 | 0 | 31 | 0.75 |
| 36 | 59 | -1 | -3 | 5.75 |
| | 60 | -4 | -5 | 5.75 |

| | Transverse Crack | Total Crack | | DMI |
|---|---|---|---|---|
| Number 8 Observation, N | 60 | 60 | 59 | 60 |
| Mean | 6.67 | 17.21 | 23.22 | 4.845 |
| Std Deviation | 26 | 60.11 | 43.68 | 5.497 |
| $t$ | 1.947 | 1.002 | 4.10 | 6.82 |
| $t_{.05}$ | 1.671 | 1.671 | 1.672 | 1.67 |

**Table 4. Pavement Surface Distress Characteristics of the Test Sections**

| Section No. | MAYS 1986 | MAYS 1990 | RCI 1986 | RCI 1990 | DMI 1986 | DMI 1990 | PCI 1986 | PCI 1990 | PCI Diff |
|---|---|---|---|---|---|---|---|---|---|
| 8-1 | 48.75 | 26.25 | 8.82 | 9.08 | 8.25 | 8.25 | 90.13 | 91.47 | 0.00 |
| 8-3 | 55.50 | 46.75 | 8.74 | 8.84 | 7.25 | 8.75 | 90.19 | 90.02 | 0.16 |
| 8-C | 45.75 | 31.50 | 8.85 | 9.02 | 7.25 | 20.25 | 90.77 | 85.60 | 5.17 |
| 13-1 | 46.00 | 51.00 | 8.85 | 8.79 | 4.50 | 6.75 | 92.02 | 90.68 | 1.33 |
| 13-3 | 42.00 | 43.50 | 8.90 | 8.88 | 6.25 | 7.25 | 91.46 | 90.91 | 0.55 |
| 13-C | 63.50 | 38.00 | 8.65 | 8.95 | 4.13 | 8.00 | 91.12 | 90.89 | 0.23 |
| 15-1 | 44.50 | 51.00 | 8.87 | 8.79 | 4.50 | 12.00 | 92.11 | 88.28 | 3.83 |
| 15-3 | 45.75 | 43.50 | 8.85 | 8.88 | 4.13 | 9.00 | 92.20 | 90.10 | 2.10 |
| 15-C | 37.25 | 38.00 | 8.95 | 8.95 | 3.13 | 20.75 | 93.18 | 85.01 | 8.17 |
| 17-1 | 89.25 | 119.25 | 8.35 | 7.99 | 6.25 | 7.25 | 88.57 | 86.25 | 2.32 |
| 17-3 | 69.00 | 59.75 | 8.58 | 8.69 | 7.00 | 10.25 | 89.48 | 88.56 | 0.92 |
| 17-C | 38.75 | 108.00 | 8.94 | 8.13 | 3.00 | 7.50 | 93.15 | 86.85 | 6.30 |
| 20-1 | 40.50 | 102.00 | 8.92 | 8.20 | 13.75 | 13.75 | 88.09 | 84.46 | 3.63 |
| 20-3 | 41.75 | 147.00 | 8.90 | 7.67 | 10.13 | 12.00 | 89.69 | 82.45 | 7.23 |
| 20-C | 37.75 | 104.75 | 8.95 | 8.16 | 5.00 | 13.00 | 92.29 | 84.63 | 7.66 |
| 21-1 | 58.00 | 83.00 | 8.71 | 8.42 | 6.25 | 7.25 | 90.49 | 88.51 | 1.98 |
| 21-3 | 55.50 | 115.00 | 8.74 | 8.04 | 7.00 | 10.75 | 90.30 | 84.99 | 5.31 |
| 21-C | 48.25 | 65.50 | 8.83 | 8.62 | 5.25 | 11.50 | 91.54 | 87.65 | 3.88 |
| 22-1 | 60.75 | 237.00 | 8.68 | 6.62 | 4.13 | 5.13 | 91.29 | 79.31 | 11.98 |
| 22-3 | 50.00 | 150.00 | 8.81 | 7.64 | 4.13 | 5.13 | 91.94 | 85.19 | 6.75 |
| 22-C | 50.00 | 212.50 | 8.81 | 6.90 | 3.13 | 8.13 | 92.40 | 79.79 | 12.61 |
| 29-1 | 53.75 | 54.00 | 8.76 | 8.76 | 7.00 | 7.25 | 90.40 | 90.28 | 0.13 |
| 29-3 | 51.25 | 45.25 | 8.79 | 8.86 | 7.00 | 11.25 | 90.56 | 88.96 | 1.59 |
| 29-C | 42.25 | 42.25 | 8.90 | 8.90 | 7.00 | 17.25 | 91.10 | 86.38 | 4.72 |
| 32-1 | 66.00 | 49.25 | 8.62 | 8.81 | 10.50 | 10.50 | 88.08 | 89.07 | 0.00 |
| 32-3 | 88.75 | 86.00 | 8.35 | 8.38 | 11.25 | 18.25 | 86.37 | 83.41 | 2.96 |
| 32-C | 81.00 | 89.25 | 8.44 | 8.35 | 8.24 | 18.25 | 88.19 | 83.22 | 4.97 |
| 34-1 | 55.50 | 41.50 | 8.74 | 8.90 | 9.50 | 11.50 | 89.16 | 89.07 | 0.09 |
| 34-3 | 81.00 | 39.25 | 8.44 | 8.93 | 7.00 | 13.50 | 88.74 | 88.28 | 0.47 |
| 34-C | 57.75 | 45.00 | 8.71 | 8.86 | 6.25 | 19.25 | 90.50 | 85.31 | 5.20 |

**Table 5. Reduction in PCI Values for Different Pavement Test Sections**

| Site No. (1) | Observation (2) | PCI Reduction | | Difference in PCI (3) - (4) |
|---|---|---|---|---|
| | | Control Section (3) | Treated Section (4) | |
| 8 | 1 | 5.17 | 0.00 | 5.17 |
| | 2 | | 0.16 | 5.01 |
| 13 | 3 | 0.23 | 1.33 | -1.10 |
| | 4 | | 0.55 | -0.32 |
| 15 | 5 | 8.17 | 3.83 | 4.34 |
| | 6 | | 2.10 | 6.07 |
| 17 | 7 | 6.30 | 2.32 | 3.98 |
| | 8 | | 0.92 | 5.38 |
| 20 | 9 | 7.66 | 3.63 | 4.03 |
| | 10 | | 7.23 | 0.43 |
| 21 | 11 | 3.88 | 1.98 | 1.90 |
| | 12 | | 5.31 | -1.43 |
| 22 | 13 | 12.61 | 11.98 | 0.63 |
| | 14 | | 6.75 | 5.86 |
| 29 | 15 | 4.72 | 0.13 | 4.59 |
| | 16 | | 1.59 | 3.13 |
| 32 | 17 | 4.97 | 0.00 | 4.97 |
| | 18 | | 2.96 | 2.01 |
| 34 | 19 | 5.20 | 0.09 | 5.11 |
| | 20 | | 0.47 | 4.73 |

Mean $y = 3.224$

$s = 2.4123$

$t = 5.97 > 1.729\ (t_{.05})$

## Evaluation of Sealant Bond Failure

Section No. _____ HWY No. _____ Date _____

Treatment Type _____ Region _____ Rout Size _____

| Crack No. | Transverse | | Longitudinal | | Bond Failure % | | | Remarks |
|---|---|---|---|---|---|---|---|---|
| | <1/2 W | >1/2 W | < 20' | > 20' | Left | Right | General | |
| | | | | | | | | |

**Figure 1/ Rout and Seal Crack Treatment Evaluation Form**

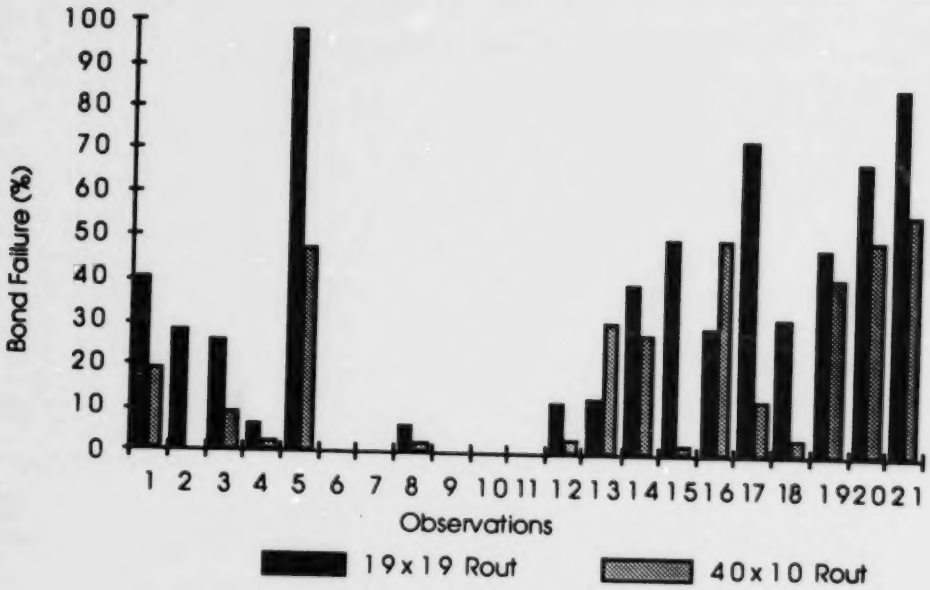


**Figure 2/ Performance of Different Rout Sizes 19x19 mm vs 40x10 mm**

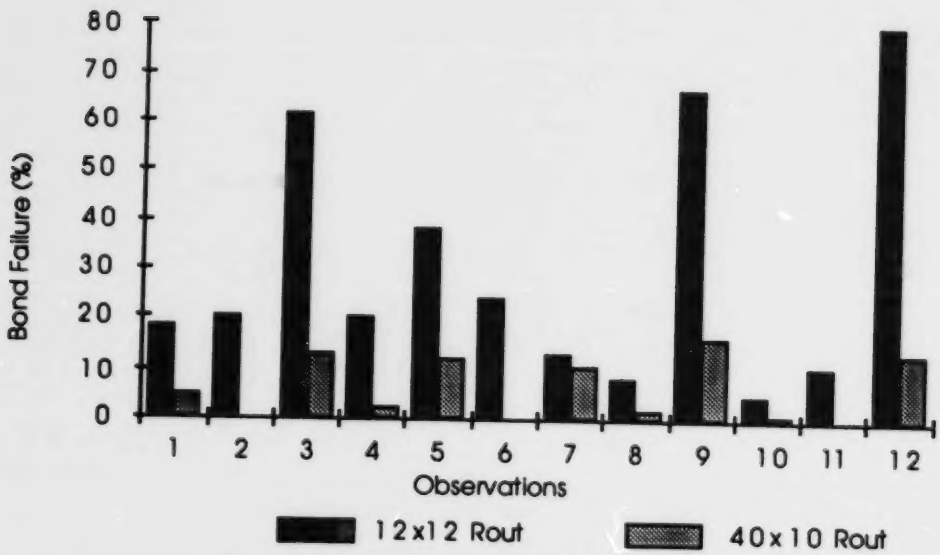


**Figure 3/ Performance of Different Rout Sizes 12x12 mm vs 40x10 mm**

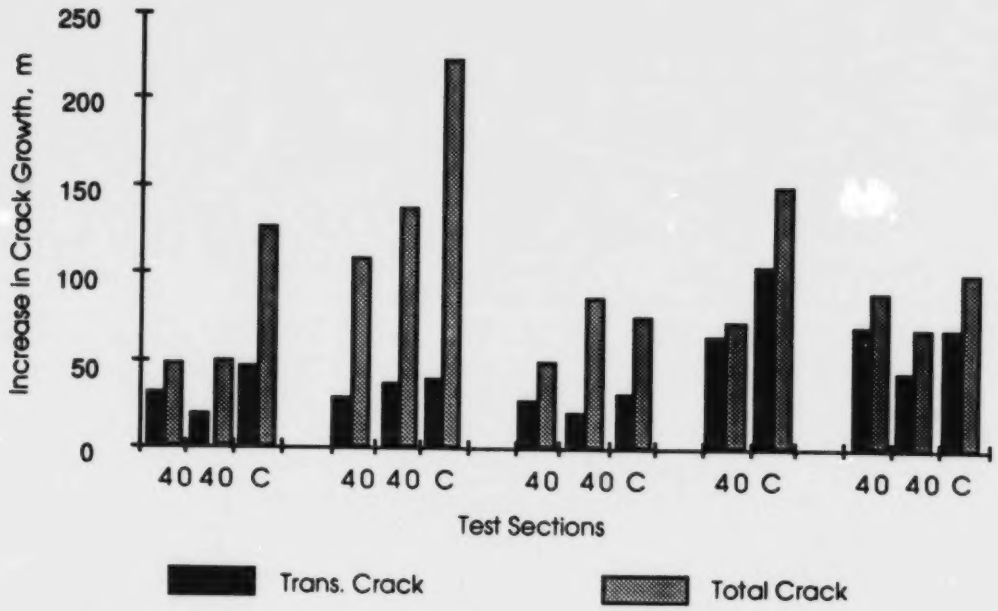


**Figure 4/ Comparison of Crack Growth in Northern Region Control vs Treated**

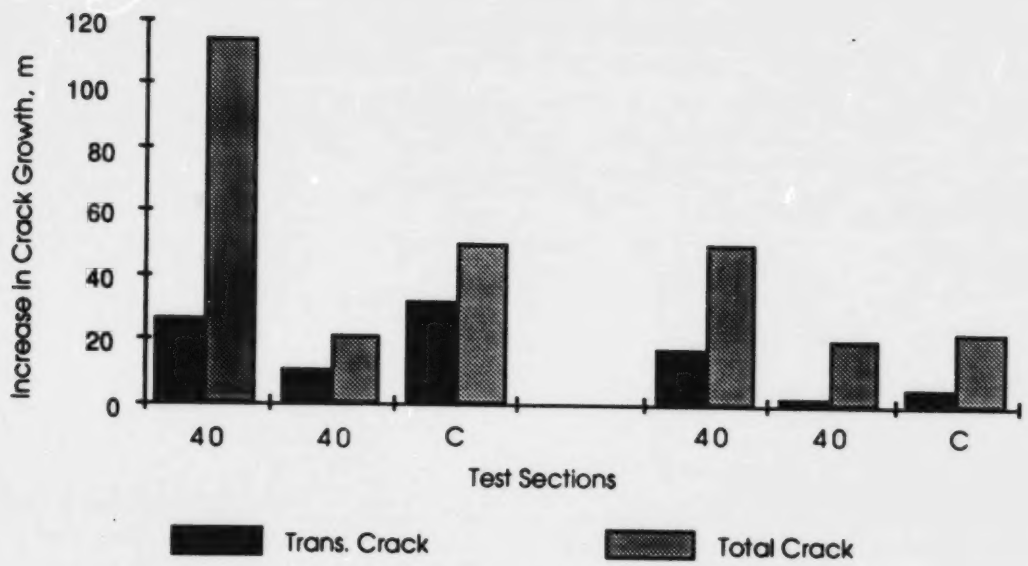


**Figure 5/ Comparison of Crack Growth in Central Region Control vs Treated**

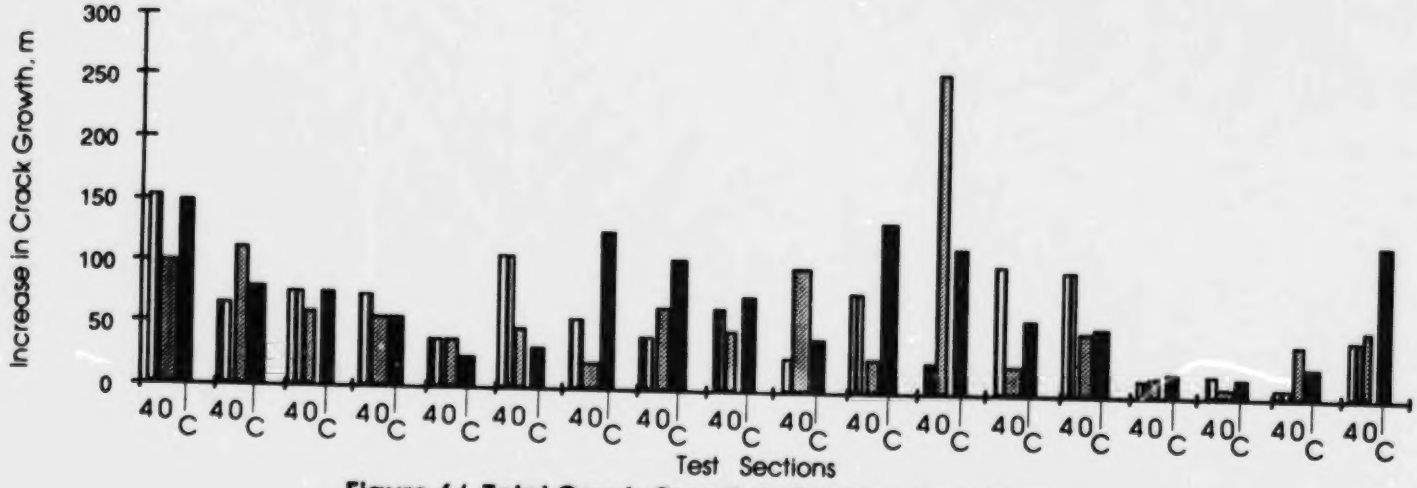


**Figure 6/ Total Crack Growth in Southwestern Region Control vs Treated**



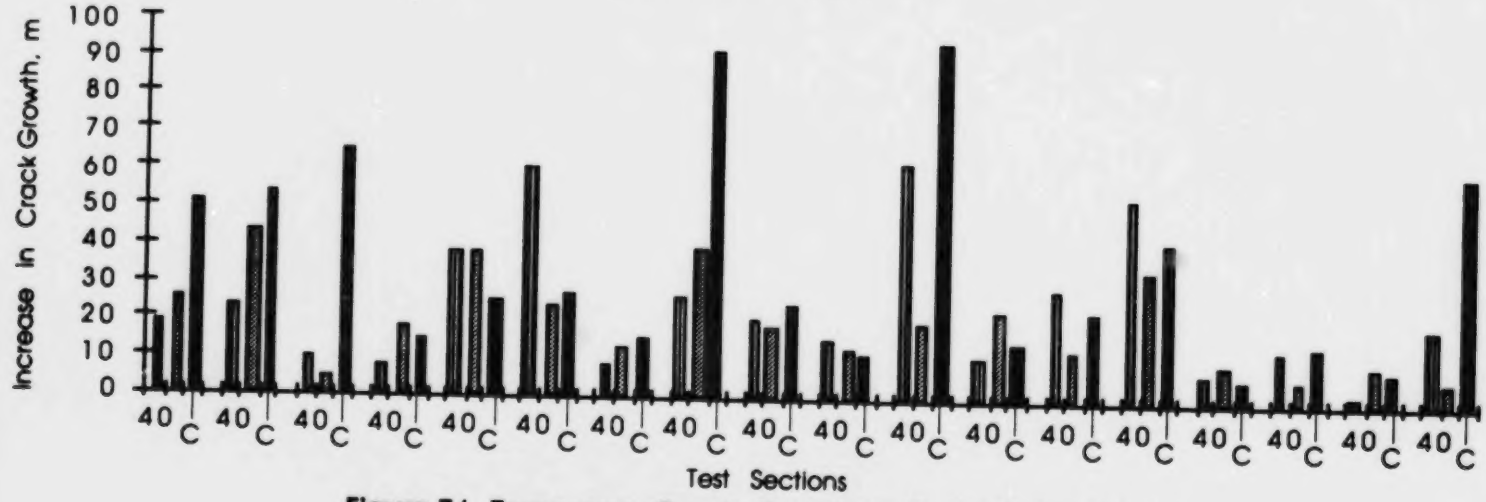


**Figure 7/ Transverse Crack Growth in Southwestern Region Control vs Treated**

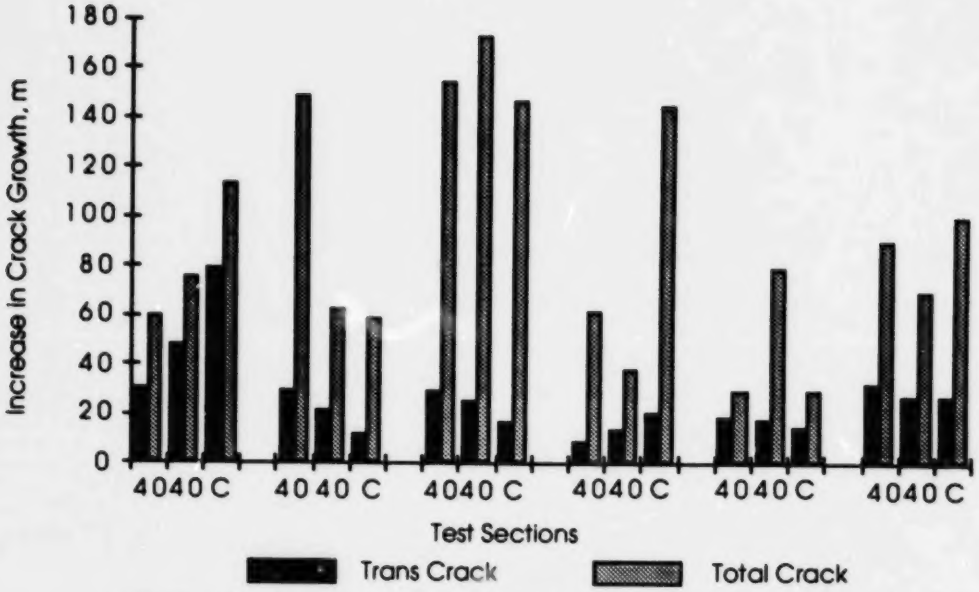


**Figure 8/ Comparison of Crack Growth in Eastern Region Control vs Treated**

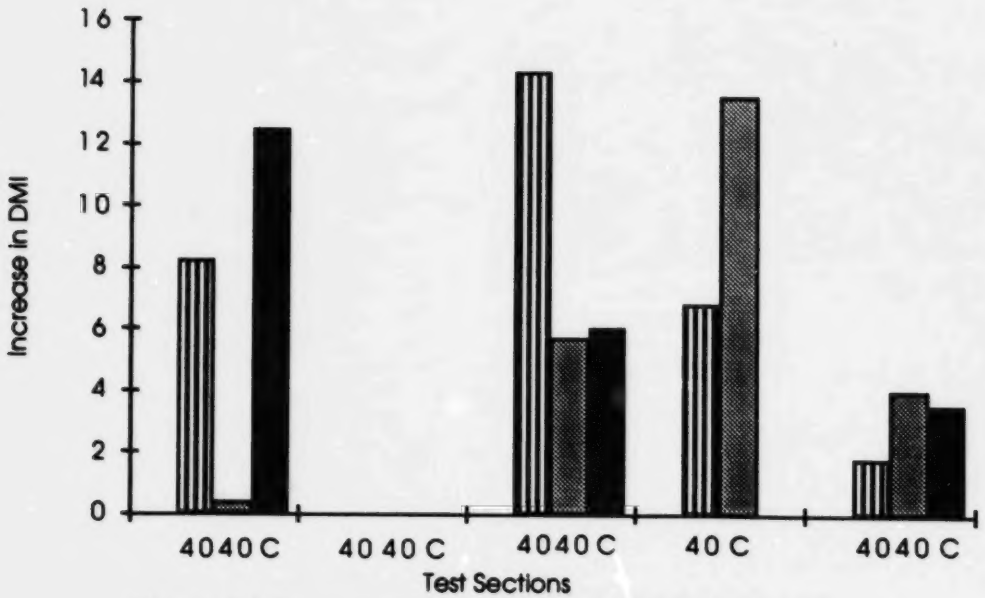


**Figure 9/ Comparison of DMI in Northern Region Control vs Treated (40 x 10)**

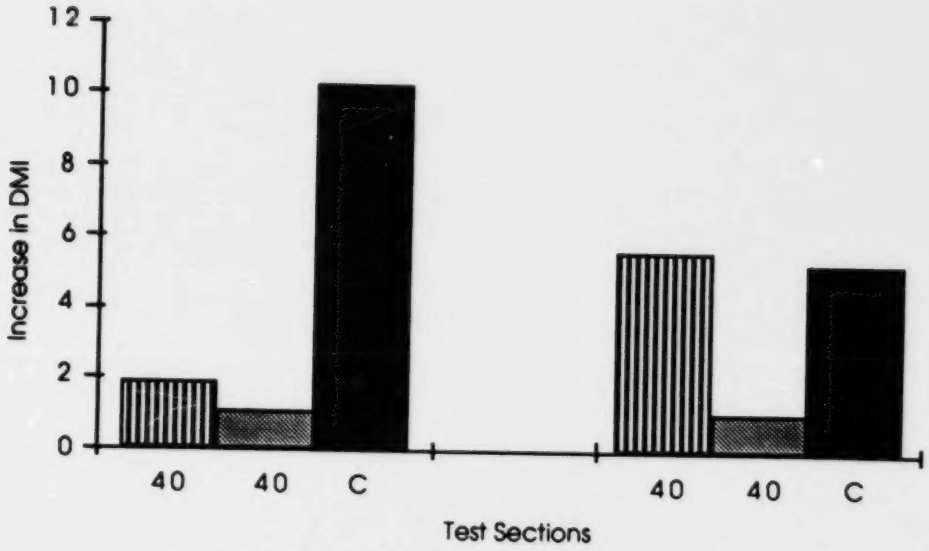


**Figure 10/ Comparison of DMI in Central Region Control vs Treated (40 x 10)**

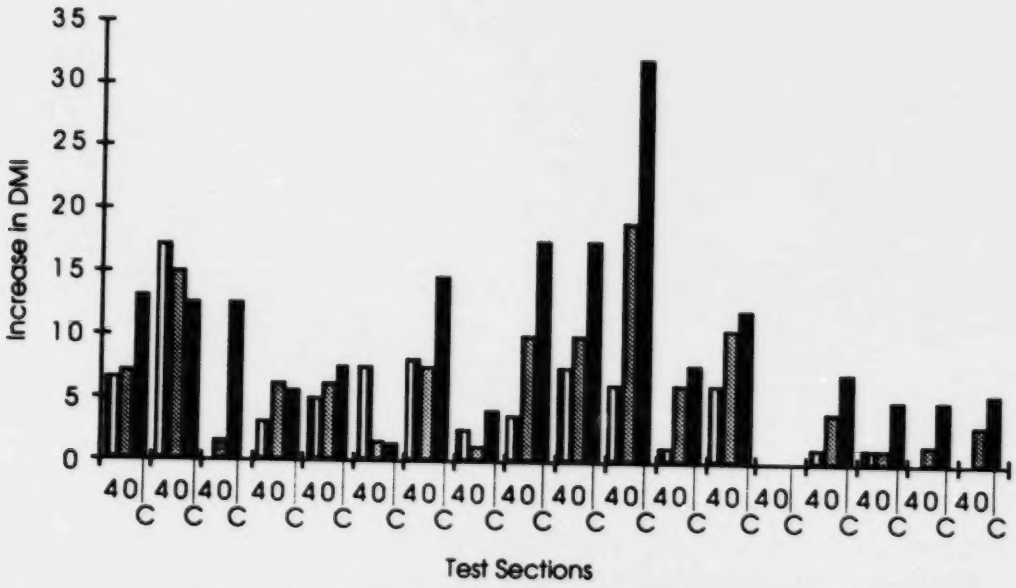


**Figure 11/ Comparison of DMI in Southwestern Region Control vs Treated (40 x 10)**

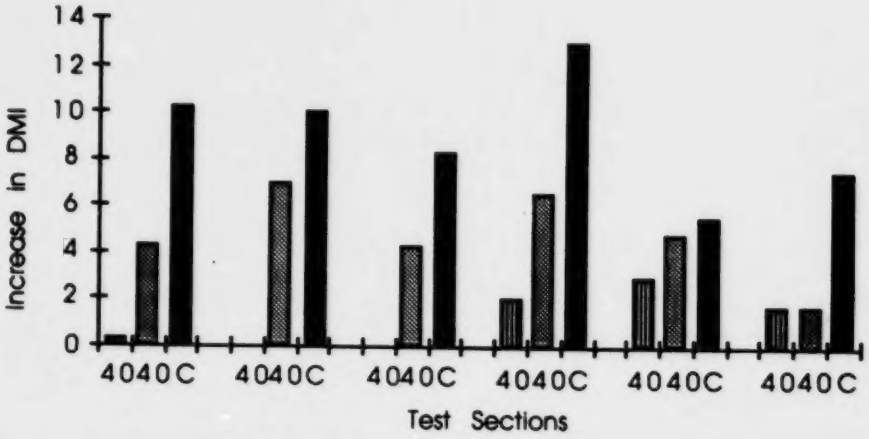


**Figure 12/ Comparison of DMI in Eastern Region Control vs Treated (40 x 10 mm)**

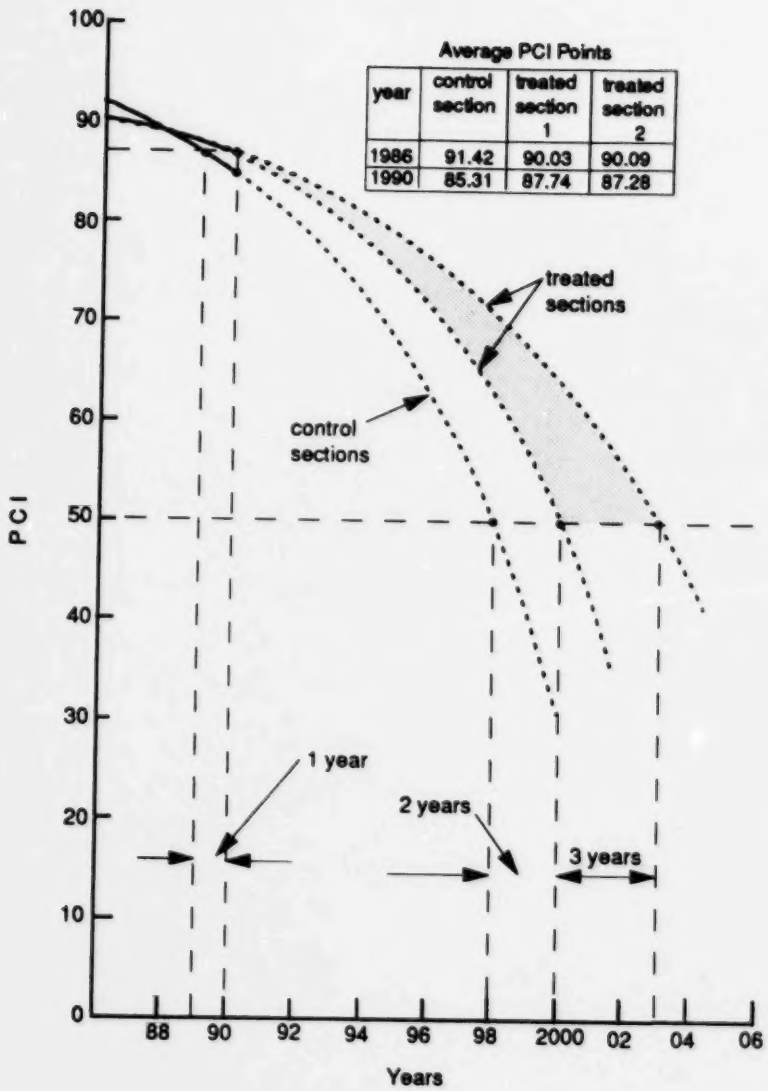


Figure 13/ Performance prediction curves
control vs. treated sections